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Microscopic investigation and magnetic properties of metal nanowires

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Arrays of nanowires (NWs) from metals of the iron group have unique properties, including magnetic ones. Possible applications of such structures are for micromagnets, for sensors, for surfaces for magnetic recording with high density (including three-dimensional [1]). One of the ways to obtain such structures is matrix synthesis using porous templates [2, 3]. There are several different ways to measure their magnetic characteristics. Thus, the measurement of hysteresis loops on a Magnetometer and the study of the Mössbauer spectra (for iron-containing samples) provides integral information about the whole NWs ensemble. Recently, some works were started on the study of the properties of individual NWs. These include measurements on SEM microscopy, TEM microscopy (Lorentz microscopy) and MFM [4, 5], in which single NWs isolated from an array were studied. In the present work, NWs arrays were obtained by the method of galvanic deposition (template synthesis) of metals into the pores of matrices – track membranes and porous alumina. The arrays of homogeneous NWs (from one metal) and the so-called layer NWs are obtained. Layer NW consists of alternating layers of Ni/Cu and Co/Cu. Preliminary study of the obtained NWs was carried out by the SEM method (Fig. 1).

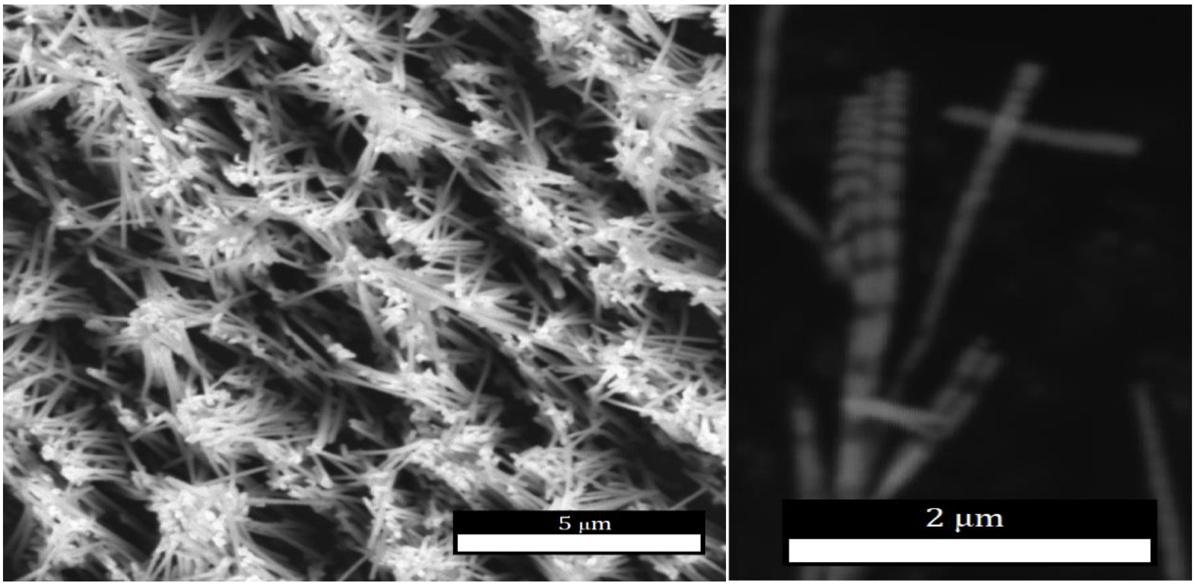
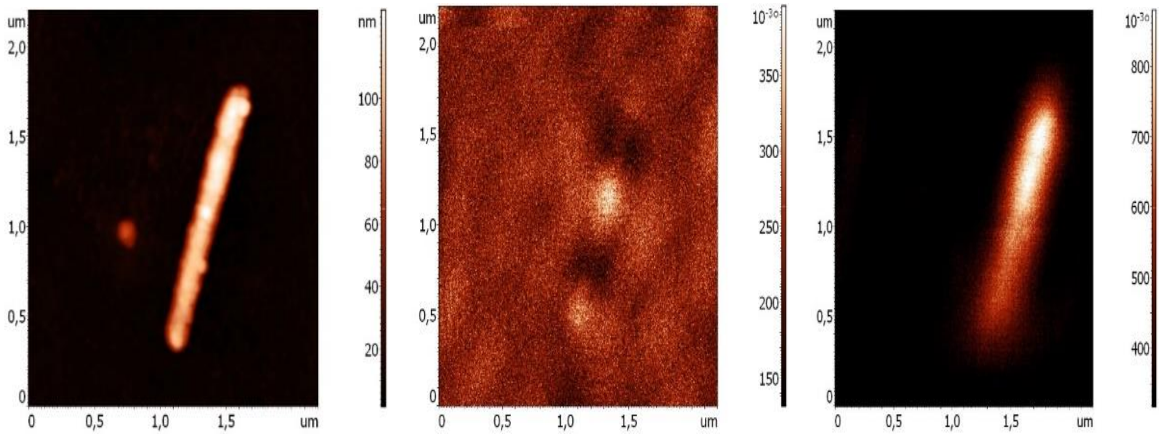


Figure 1. SEM images of layer NWs.

It is shown that NWs grown in the track membrane completely fill the pore channels, and their diameter is somewhat higher than the pore diameter. The TEM study (conducted earlier in [6] for Ni/Cu nanoparticles) made it possible to determine the thicknesses of alternating layers (from 30 to 250 nm). Elemental analysis showed that alternating layers consist of pure copper and nickel-copper alloy (up to 20% copper). For probe microscopy Solver P47 Pro with cantilevers Multi75M-G (BudgetSensor) was used. For AFM measurements, NW suspension in water was deposited on the holder by the "irrigation" method, followed by drying and then covered by a thin layer of metal (by thermal sputtering). For MFM measurements, the one-pass technique was used in order to avoid the influence of neighboring NWs on each other. Figure 2a shows the AFM images of the topography of a single layer Co /Cu NW, Figure 2b shows the MFM image of the same NW, and Figure 2c shows the MFM image after an external magnetic field 16 mT was applied along the NW axis.



(a) (b) (c)

Figure 2. (a) an AFM image of a layer NW (Co/Cu), (b), (c) an MFM images of the same NW (b – without field, c – with application of an external field).

It is seen that the NW is divided into regions of different magnetization, and the application of the external field changes this state. AFM/MFM measurements of NWs grown in the pores of the Alumina Oxide (POA) matrix were also performed. Measurements were done at the cut of the POA. The results are presented and discussed.

So, the fragmentation of NWs into domains was demonstrated and the influence of NWs to each other was concluded.

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